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Canada. Geodetic Survey

DEPARTMENT OF THE INTERIOR, CANADA

HON. CHARLES STEWART, Minister — W. W. CORY, Deputy Minister

GEODETIC SURVEY OF CANADA

NOEL J. OGILVIE, Director

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ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1925

1924/25

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CONTENTS

ILLUSTRATIONS

PLATES

MAP

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GEODETIC SURVEY OF CANADA

REPORT OF THE DIRECTOR, NOEL J. OGILVIE

The work of the Geodetic Survey has progressed satisfactorily, both in the field and in the office, and this year has been a successful one.

The National Committee of Canada of the International Union of Geodesy and Geophysics was represented at the Second General Assembly of the International Geodetic and Geophysical Union.

Geodetic Survey operations were carried out in all nine provinces of the Dominion during the field season of 1924.

SECOND GENERAL ASSEMBLY OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION

The Director had the honour to be elected a delegate by the National Committee of Canada of the International Union of Geodesy and Geophysics to represent Canada at the Second General Assembly of the Union, held in Madrid, Spain, in October, 1924.

The purpose of the International Union is to promote the study of problems relating to the shape and physics of the earth; to initiate and organize the conduct of researches which depend on co-operation between different countries, and provide for the scientific discussion and publication of results; to facilitate work along particular lines, such as the comparison of instruments and methods used in different countries.

The International Union is divided into sections corresponding to the National Committees of the different countries belonging to the Union. One hundred and seventy-two delegates, representing thirty-two countries, proceeded to take up the work of the Union, dividing into sections as follows: Geodesy, sixty-five; Seismology, fifteen; Meteorology, eighteen; Terrestrial Magnetism and Electricity, twenty-four; Physical Oceanography, twenty-eight; Volcanology, ten; and lastly, a new and important section, Scientific Hydrology.

The opening session of the General Assembly, previous to dividing into these sections, was held in the palace of the Chamber of Deputies, and was opened by the King of Spain. The first part of this meeting was taken up by delegates who presented reports of the work accomplished in their respective countries, since the first meeting of the International Union at Rome in 1922. A large part of the remainder of the time was occupied in completing the organization started at the previous meeting at Rome. A number of scientific papers were read. Special committees were formed to report on improvements on instruments and methods of carrying out scientific work in the various countries belonging to the Union.

Four outstanding features of the conference were:—

(1) A committee formed to carry out or establish a longitude net around the world by wireless, to be used in checking the fixity of the continents. The Director of the Geodetic Survey was made a member of this Committee.

(2) The paper presented, under the Section of Oceanography, by Admiral Sir John Parry on The Gulf Stream. This paper was prepared by one of our distinguished Canadian scientists, Dr. W. Bell Dawson, whose name is known in every country as an authority on tides and currents.

(3) The discussion on the determining of distances between two points through the velocity of light.

(4) The adoption of the Hayford Ellipsoid of 1909, as a standard of reference for all countries.

At the final meeting reports of the various sections were adopted and a decision made as to the place of meeting for the third conference.

The invitation of the Czecho-Slovakian Republic to hold the third conference of the Union at Prague in September, 1927, was accepted.

The delegates had the privilege of visiting a number of scientific institutions in Spain and excursions were planned by the National Committee of Spain for the delegates to visit a number of places of scientific interest.

Canada has taken a prominent part in the work and organization of the Section of Geodesy of the International Union of Geodesy and Geophysics, and the accuracy as well as the extent of Canadian geodetic operations was recognized by the delegates from the various countries forming the Union.

ASTRONOMICAL POSITIONS AND THEIR ERRORS

In various annual reports the many advantages accruing from the adoption of the North American Datum as a basis for all triangulation of this Survey have been given, and attention has been drawn to the difficulty of controlling surveys made with any fair degree of precision, by astronomical observations. The latter observations are made with every regard to precision but the result is always affected by the deflection of the vertical. This in most cases produces errors in astronomical positions of sufficient size to render their use for control purposes in distance valueless except for exploratory or other local surveys.

A good example of this is obtained at Sugar Loaf in Cape Breton island where the meridian deflection amounts to plus 1527·2 feet, the maximum so far observed in Canada. Sixty miles to the south at Sydney it is but plus 7.1 feet. Hence, a control for distance between these points based on astronomic values would show an error of 1520·1 feet in latitude, or expressed as a ratio of the intervening distance, 1 part in 211. It is thus seen that astronomic values may introduce errors of scale much larger than the errors of a survey of low grade accuracy.

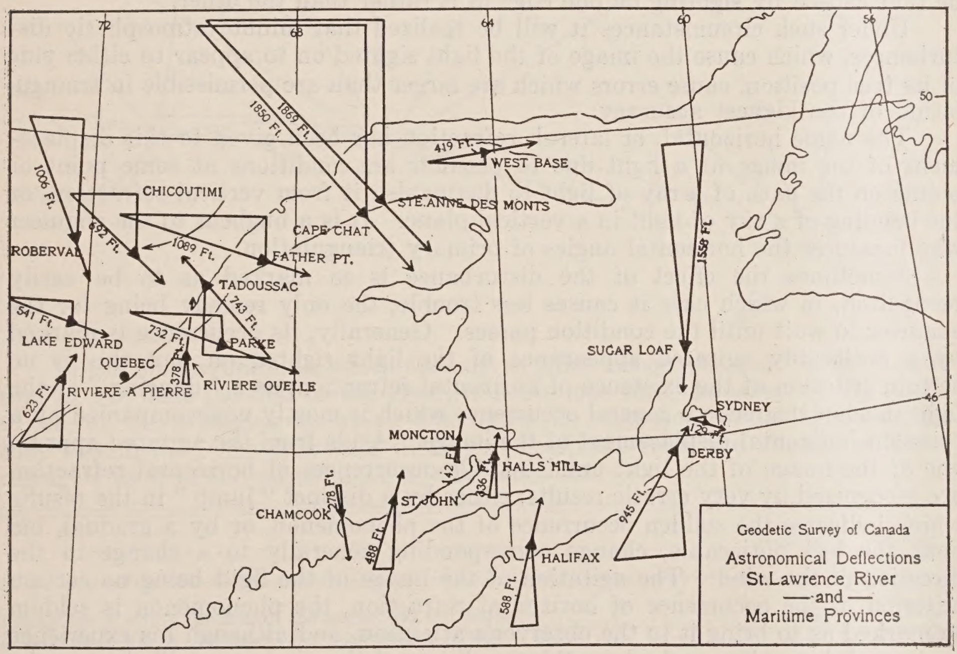
The following table shows a number of examples of the error which would result from employing representative astronomical stations as distance control. A number of the stations in the St. Lawrence area are indicated on the plate on page 7.

Between Stations	Distance	Combined Error of Astr. Stations Expressed as Ratio of Intervening Distance	
Pacific Coast—	Miles		
Oldfield to Klucksiwi	290	1 : 1,270 or	4·2 ft. in 1 mile
Klucksiwi to Lazo	123	1 : 1,380	3·8 " "
Lazo to Little Mountain	95	1 : 415	12·7 " "
Southern Ontario—			
Southwold to Collingwood	157	1 : 2,260	2·3 " "
Collingwood to Murray	130	1 : 900	5·9 " "
Murray to Ottawa	130	1 : 1,800	2·9 " "
Ottawa to Vankleek	54	1 : 385	13·7 " "
Lower St. Lawrence—			
Tadoussac to Chicoutimi	66	1 : 243	21·7 " "
Lake Edward to Tadoussac	126	1 : 535	9·9 " "
Tadoussac to Father Point	64	1 : 190	27·8 " "
Father Point to Cape Chat	90	1 : 430	12·3 " "
Ste. Anne Des Monts to Anticosti	117	1 : 370	14·3 " "
Southern New Brunswick—			
Chamcook to St. John	52	1 : 370	14·3 " "
St. John to Moncton	84	1 : 1,260	4·2 " "
Moncton to Hall's Hill	31	1 : 840	6·3 " "
Cape Breton Island—			
Derby to Sydney	32	1 : 190	27·8 " "
Sydney to Sugar Loaf	59	1 : 200	26·4 " "

The average error in distance shown in the above table is 1 in 767, or about 7 feet in a mile, with errors as large as 1 in 190. As the error in distance of modern block outline land surveys is less than 1 in 10,000 and that of average modern subdivision surveys and chained traverses from 1 in 4,000 to 1 in 8,000, while the error in distance in modern stadia traverses is at least 1 in 500, it will be appreciated that the statement above as to the unreliability of astronomical positions for checking the accuracy of surveys is not overdrawn.

No information is yet available for the Prairie Provinces, but it is anticipated that this phenomenon will not operate with as great force as in the instances noted above.

With the expansion of the Canadian triangulation net, information is obtained from time to time of the exact amount of the deflection. On the accompanying sketch the deflections for 19 stations are shown on an enlarged scale, the co-ordinates of these deflections in the meridian and prime vertical being given in feet and based on the position of the station as given by the geodetic value. The hypotenuse of the triangle indicates the plane of the deflection with reference to the meridian, while the arrow gives the direction in which the nadir is deflected owing to local attraction.



Geodetic Survey of Canada
Astronomical Deflections
St.Lawrence River
—and—
Maritime Provinces

As the arrows give the direction of areas of excessive density it is possible to determine a rough outline of these areas where the stations are suitably located and sufficiently close to one another to make definite conclusions. The work along the British Columbia coast is as yet too inadequate for such a determination, as likewise is that throughout Ontario, except to say that apparently the effect of the local topography predominates over that more distant from the station.

The St. Lawrence River series definitely locates an area of excessive density within the region bounded by Quebec, Roberval, and Tadoussac. Farther east those on the south shore of the river are attracted towards the Gaspé peninsula where the Shickshock mountains attain elevations up to 4,000 feet. Sufficient information is not yet available to analyse the effect of these mountains on those

stations along the bay of Fundy. During the coming summer triangulation operations will furnish values at Campbellton, N.B., which will give further interesting information concerning this area. Other information will also be available from year to year which will be exceedingly valuable in studies of the figure of the earth and the theory of isostasy.

In this connection the Annual Report of the Superintendent of the Geodetic Survey, 1920, pages 13-15, will also be of interest. A few years ago there was a prevalent misconception as to the use of astronomical stations. This is now largely disappearing.

LATERAL REFRACTION

As atmospheric conditions at night are apt to be more uniform than in the daytime, the measurements of horizontal angles on the highest grade of triangulation are usually made at night, the pointings being made on electric signal lamps. The accuracy attained on these measurements is not commonly realized. It is such that should a 2-inch side of an erect scantling at a distance of 18 miles face the observer, the permissible error of angular measurement would be that caused by sighting on one edge of it rather than the other.

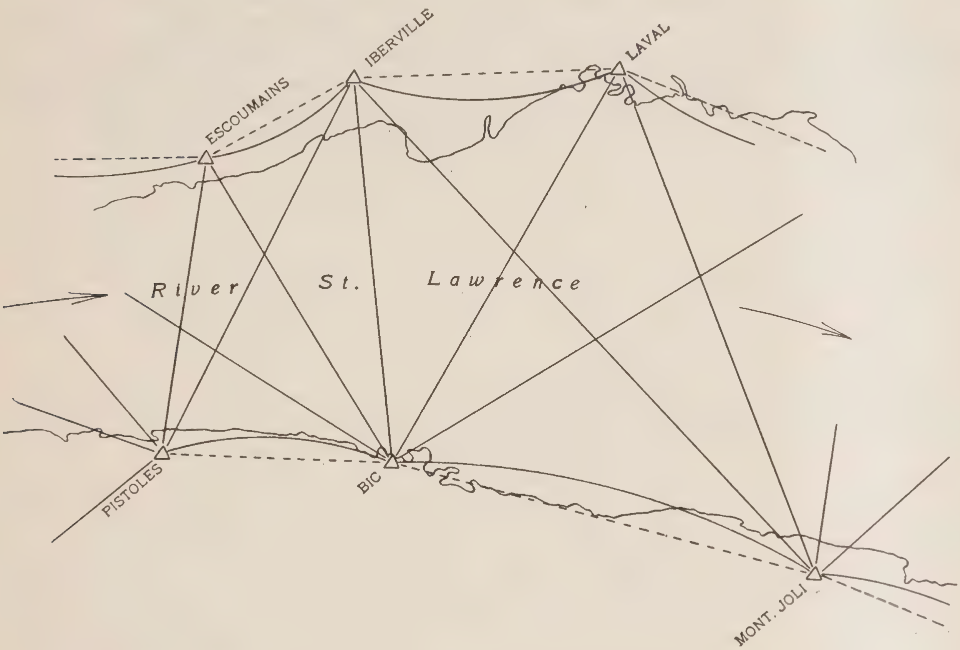
Under such circumstances it will be realized that minute atmospheric disturbances, which cause the image of the light sighted on to appear to either side of its true position, cause errors which are larger than are permissible in triangulation of the highest accuracy.

The name horizontal, or lateral, refraction has been given to this displacement of the image of a light due to peculiar air conditions at some point or points on the path of a ray of light to distinguish it from vertical refraction, or the bending of a ray of light in a vertical plane. It is a bugbear to the engineer who measures the horizontal angles of primary triangulation.

Sometimes the effect of the disturbance is so marked as to be easily recognized, in which case it causes less trouble, the only remedy being for the engineer to wait until the condition passes. Generally, its occurrence is marked by a noticeably agitated appearance of the light sighted on, but this is no certain criterion of the existence of horizontal refraction, as a " dancing " of the light in some degree is a general occurrence which is mostly unaccompanied by a constant horizontal displacement of the image. Aside from the agitated appearane of the image of the light unmistakable occurrences of horizontal refraction are recognized by very erratic results, either by a distinct " jump " in the results which indicates the sudden occurrence of the phenomenon, or by a gradual, but none the less noticeable, change corresponding generally to a change in the direction of the wind. The agitation of the image of the light being no certain criterion of the occurrence of horizontal refraction, the phenomenon is seldom so marked as to bring it to the observer's attention, and although his experience may teach him when and where this condition of the air is most likely to exist he can never be sure that the images of his lights have not been laterally displaced until the combination of results at different stations furnishes him with checks on the accuracy of his work and shows him whether or not any large errors exist.

Instances of horizontal refraction have been met with at Claydon triangulation station in southern Saskatchewan and at Kilkenny station in the Quebec triangulation, but the most extended and persistent example yet encountered was met with in connection with the St. Lawrence and Gulf net. The lines along the river bank were so consistently " bent " towards the river that a practice had to be adopted to complete observations on these lines only when the results on at least two nights showed a satisfactory agreement. Horizontal refraction affecting the observations by from 5 seconds to 15 seconds of arc

was not at all uncommon and it has been estimated that almost three times the amount of clear weather ordinarily necessary to seecure the required program of observations was used to secure the required accuracy. Even with the precautions which were taken the evidence shows a regular "bending" towards the river of the lines parallel to the river. This is evidenced by the error of closure of triangles, the sum of the three observed angles being less than the theoretical sum in the majority of cases.



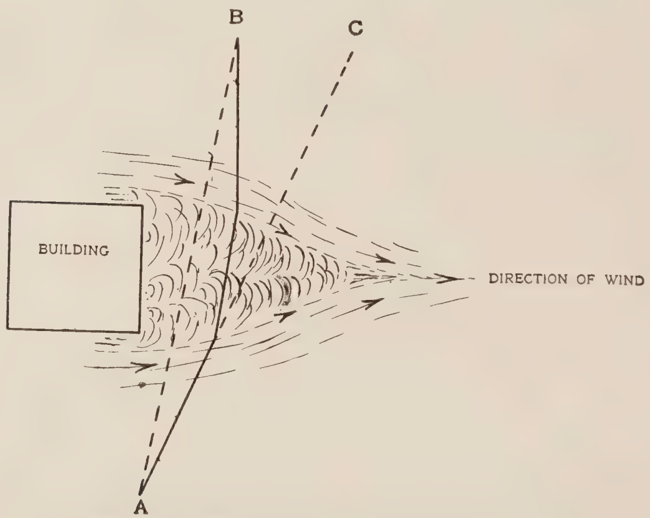
In the above figure, in which the curved lines exaggerate the " bent " condition of the lines parallel to the river, it is obvious that the sums of the angles of all of the triangles of which the figure is composed would be less than they should be. The following table was compiled from the closure errors of triangles used in the adjustment of this large net:—

—	Number	Average Error
Triangules in which the sum of the angles was too small	42	$-1''\cdot107$
Triangules in which the sum of the angles was too large	12	$+0''\cdot700$

Had only accidental errors entered into the measurement of the angles of this net, approximately the same number of positive as negative closing errors would have been expected. The last column indicates that even where the sum of the angles was too large the errors were probably reduced by the " bending " indicated above. This information may be stated in another way. In the adjustment of this net the large majority of the corrections to the lines parallel to the river " unbent " these lines away from the river. Of 66 such corrections to directions 54 produced this kind of straightening of the corresponding lines, while only 12 produced the reverse effect; also the average magnitude of these 54 corrections was $0''\cdot450$ while that of the 12 was only $0''\cdot257$, indicating a great preponderance both in number of bent lines and magnitude of the correc-

tions. In contrast with the above constant tendency of the lines parallel to the river to bend towards the river, it may be mentioned that the adjustment gave to the lines crossing the river 62 positive corrections averaging $0''.343$ and 61 negative corrections averaging $0''.316$, which indicates errors of the accidental, in distinction to those of the constant, type.

Several explanations may be advanced for the cause of horizontal refraction. Unequal heating of the land over which a line passes, such as ploughed fields, forests, etc., during the day, followed by unequal cooling at night may no doubt cause " pockets " of air of different density which may have a prismatic effect on the rays of light passing through them. This would produce a change in direction of the line of sight and the image of the light would be seen to one side of its true position. The same prismatic effect would be produced where a line passes on the lee side of a high building, chimney or mountain mass.



Thus an observer at A would see the light B at C, the angular error being the angle BAC.

The explanation of the persistent occurrence of horizontal refraction on the St. Lawrence River and Gulf net is probably different. The shores of the river are high and the prevailing night winds were " on shore " winds, so that the explanation above regarding the effect of wind does not hold in this case. What probably happened was that the strata of air of different density frequently did not lie horizontal, as is generally assumed, but followed more or less closely the surface of the land. Lines along the hilly shore passed through air strata which probably dipped slightly towards the river, and the plane of the curved path of the light, being perpendicular to the strata, was inclined towards the river, the light hence appearing, above and *slightly to the river side* of its true position instead of directly above, as would be the case were the strata of air horizontal. This theory accounts for the fact that on lines *across* the river no evidence of lateral refraction exists.

Atmospheric conditions favourable to the occurrence of horizontal refraction are seldom of long duration; rarely do they extend over a period longer than a few hours, a change in the direction of the wind being usually a sign for their disappearance. The occurrence and magnitude of the displacement can never be predicted with certainty and the obvious and only known remedy is to obtain observations on different nights, when the atmospheric conditions

tend to be different. This phenomenon is of such rare occurrence that the reoccupation of an occasional station is cheaper than the requirement that observations be spread over at least two nights to secure a comparison of results. Obviously, however, where consistent lateral refraction is found, some such action is the only recourse.

TRIANGULATION OPERATIONS

In all areas the season of 1924 was a successful one. Favourable weather permitted the field parties to make very satisfactory progress—even more so, in general, than in 1923 which was considered a very good season.

Operations in two difficult areas were completed—the connection between Cape Breton island and Newfoundland across Cabot strait, and that from the southerly portion of the Queen Charlotte islands to the mainland of the British Columbia coast. In both of these areas long lines and the prevalence of fogs have been very great obstacles to satisfactory progress, and it is highly gratifying that the completion of operations in these areas permits the rapid progress of triangulation in other districts where it is urgently required.

A résumé of the progress in the different provinces follows:—

Nova Scotia.—The triangulation connection between Cape Breton island and Newfoundland was completed in July, 1924. This early conclusion was made possible owing to exceptionally favourable weather conditions, which were in marked contrast to those of the previous season.

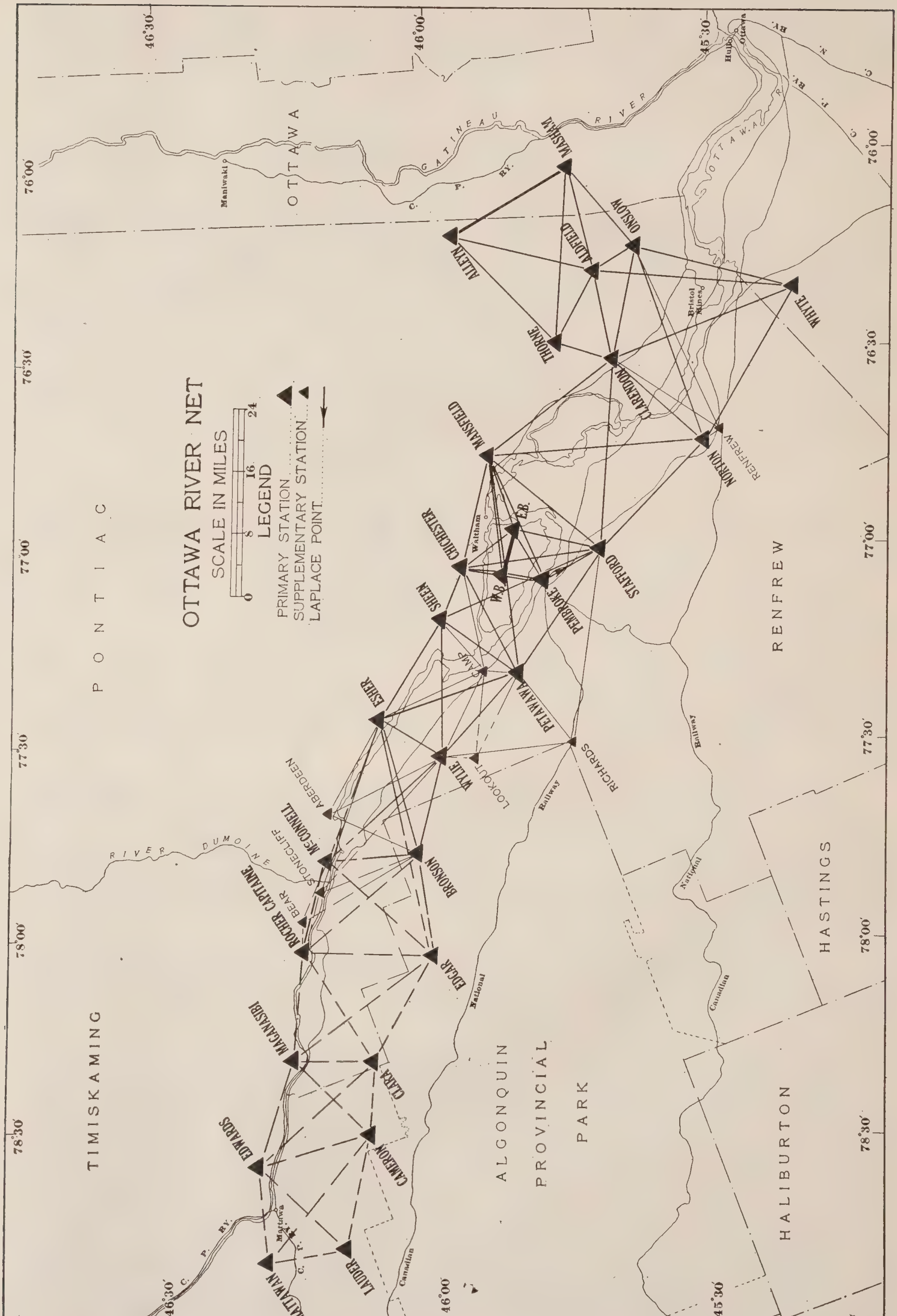
Late in the autumn reconnaissance for selection of triangulation stations was begun in the area from Digby to Yarmouth, N.S.

Prince Edward Island.—Operations on the island consisted only of the reconnaissance for the selection of a few stations along the north side of Northumberland strait to fill in a gap which had been left there. Angular measurements in this area will be made in 1925 or 1926 by the party which is working south from Chaleur bay.

New Brunswick.—Splendid progress was made in the primary triangulation along Chaleur bay. Many lighthouses and church spires along the coast were located by intersection and will provide very convenient geographic information for charting purposes. Only four stations remain to be occupied to complete the connection with the St. Lawrence River triangulation. This will be accomplished early in 1925, after which the work will proceed southward along the east coast of New Brunswick.

Secondary triangulation was carried on during the season of 1924 in the Fredericton area to provide control for mapping by the Topographical Survey. A sketch of this work appears on page 27.

Quebec.—In the Gulf of St. Lawrence area only a reconnaissance party operated. The party first made a preliminary reconnaissance of the easterly half of Anticosti island, to determine the feasibility of extending control along the shore by precise traverse. It was found that this was quite possible along the south shore from Southwest point eastward to Heath point, but not feasible along the north coast from Heath point west to Observation point on account of the high cliffs and the absence of a beach in the latter stretch. The party then moved to the north shore and continued the selection of triangulation stations eastward from the end of the work of the winter of 1923-24 in longitude 60°. Stations were selected almost as far as Mutton bay in longitude 59°. Reconnaissance is 200 miles east of the angular measurements. A further distance of about 200 miles is still to be covered to bring the reconnaissance to the strait of Belle Isle.


OTTAWA RIVER NET
SCALE IN MILES
0 8 16 24
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LAPLACE POINT
PONTIAC
OTTAWA
TIMISKAMING
RENFREW
HASTINGS
HALIBURTON
ALGONQUIN PROVINCIAL PARK
GATINEAU RIVER
OTTAWA R.
DUMOINE RIVER
MASHAM
ONSLOW
ALDFIELD
ALLEYN
WHYTE
THORNE
CLARENDON
MANSFIELD
NORTON
RENFREW
CHICHESTER
STAFFORD
PEMBROKE
SHEEN
PETAWAWA
CAMP
ESHER
WYLIE
LOOKOUT
RICHARDS
ABERDEEN
McCONNELL
STONECLIFF
BEAR
ROCHER CAPITAINE
BRONSON
EDGAR
MACKAWASKI
CLARA
CAMERON
EDWARDS
LAUDER
MATTAWAN
Maniwaki
Hull
Ottawa
Bristol Mines
Waltham
Mattawa
C. P. RY.
46°30'
46°00'
45°30'
76°00'
76°30'
77°00'
77°30'
78°00'
78°30'

Another link was completed in the loop of secondary triangulation which may be called the Saguenay River-Lake St. John-Three Rivers loop. Several points of particular importance for the mapping of that country were located, such as astronomical stations on which the mapping of the area had been based. One more season will see the completion of this loop, which has a total length of some 480 miles, of which 140 miles is secondary triangulation and the balance primary.

Ontario and Quebec.—In the Ottawa River area the primary triangulation was advanced approximately 80 miles during the season of 1924, and stations have been selected ahead as far as Mattawa, 200 miles from the commencement of the net. Above Pembroke this net lies in country in which transportation is confined to a single road along the Ottawa river as far as Mattawa, with short lateral trails or winter "tote" roads at intervals. See map of the net on page 12.

Manitoba.—It was decided to cover the area at the eastern end of the arc of triangulation along the 49th parallel, (a distance of 76 miles) by precise traverse along the Canadian National railway instead of by triangulation, on account of the flat, marshy, wooded nature of the country, which would have rendered triangulation slower and more expensive. At the request of the International Boundary Commission this section from Emerson, Man., to lake of the Woods was completed in 1924 to furnish the commission with final geographic positions along this section of International Boundary as soon as possible. Under the previous program this work would not have been completed until 1925.

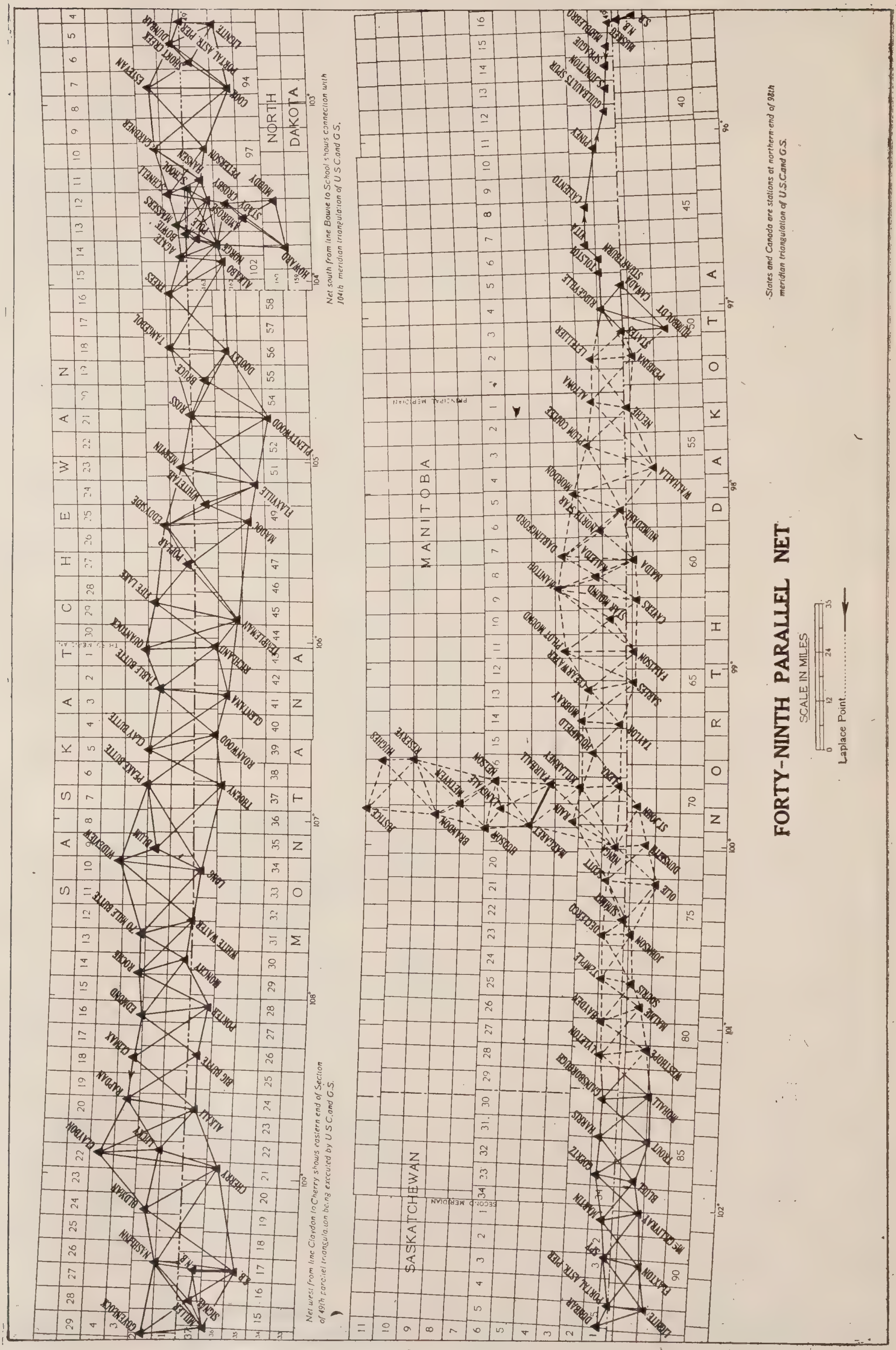
This traverse forms part of an international co-operative movement of importance to both the United States and Canada. At the west end it connects, near Emerson, Man., with the 98th Meridian net of the United States Coast and Geodetic Survey. At the Lake of the Woods end it joins a precise traverse run by the same organization which, with triangulation of both Canadian and United States geodetic surveys completes the primary control along the International Boundary from the 98th meridian, as far east as lake Superior. A map of the net appears on page 14.

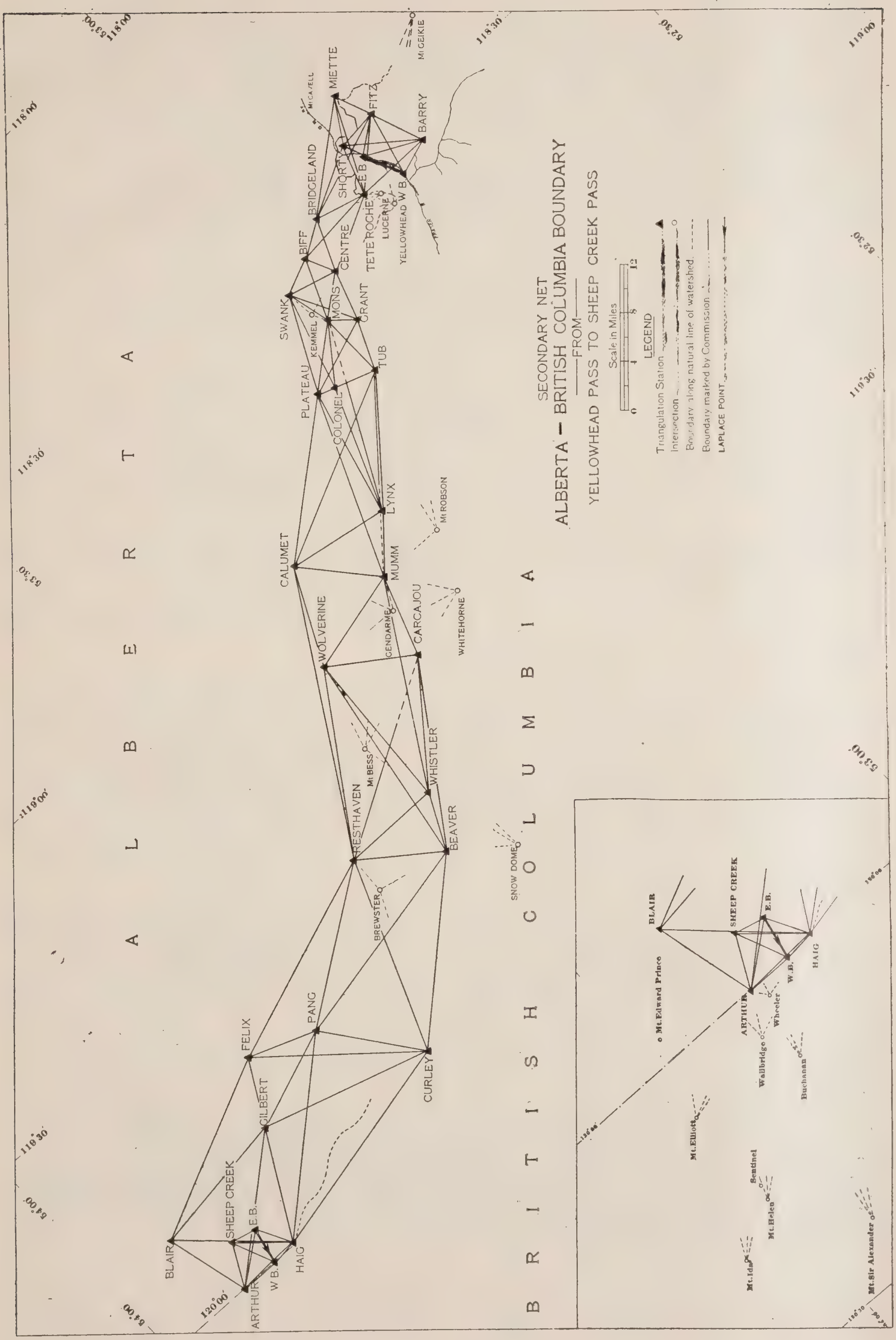
Saskatchewan.—On the completion of the precise traverse noted above in July, 1924, the parties moved to Saskatchewan to continue the original program of working east. The angular measurement was carried forward almost to the boundary between Saskatchewan and Manitoba, while the building of towers on the whole area was completed and the marking of stations almost finished.

The season of 1925 will mark the completion of the work on the Canadian section of the triangulation along the 49th Parallel International Boundary. Progress on the more difficult western half of this net by the United States Coast and Geodetic Survey has also been very satisfactory. A map of the net is shown on page 15.

Alberta.—A secondary triangulation of the Spray Lakes district in the Rocky Mountains park was carried out. Fourteen stations were established, four at elevations of over 7,000 feet and a base line was measured on the Upper Spray lake. A line of levels was carried from a Geodetic Survey precise level bench-mark on the Canadian Pacific railway to an altitude of 5,800 feet on the northerly side of Wind mountain; from there across the Wind Mountain divide elevations were carried by trigonometric levelling into the Spray valley. This work was completed on December 13.

Alberta—British Columbia.—The secondary triangulation along that part of the Alberta-British Columbia boundary following the summit of the Rocky mountains northward from the Yellowhead pass at Jasper, Alta., an air-line


FORTY-NINTH PARALLEL NET
SCALE IN MILES
Laplace Point
SASKATCHEWAN
MANITOBA
MONTANA
NORTH DAKOTA
Net south from line Bowie to School shows connection with 104th meridian triangulation of U.S.C.and G.S.
Net west from line Claydon to Cherry shows eastern end of Section of 49th parallel triangulation being executed by U.S.C.and G.S.
States and Canada are stations at northern end of 98th meridian triangulation of U.S.C.and G.S.


SECONDARY NET
ALBERTA – BRITISH COLUMBIA BOUNDARY
FROM
YELLOWHEAD PASS TO SHEEP CREEK PASS
Scale in Miles
LEGEND
Triangulation Station
Intersection
Boundary along natural line of watershed
Boundary marked by Commission
LAPLACE POINT
ALBERTA
BRITISH COLUMBIA

distance of about 100 miles, was completed in 1924. The angular measurements on the whole area were made by three parties during the short season (usually less than three months); a base-line was selected and measured at the north end, and Laplace (coincident triangulation, longitude and azimuth) stations were established at both north and south ends. A base line had previously been measured on the ice at Yellowhead lake at the south end during January and February, 1923.

This net has not been connected to the primary triangulation of this Survey; it cannot be placed on the North American Datum until it has been so connected, and hence its geographical position will be subject to revision when the triangulation along the Canadian National railway eastward from Prince Rupert to Edmonton is completed. In anticipation of that event Laplace stations (astronomical longitude, azimuth at triangulation points) have been established at the north and south ends of the net respectively; astronomical latitudes were observed at these points for present geographical needs and also to serve in future studies of the figure of the earth.

In the meantime the geographical position of the net may be determined in three ways: from the astronomic stations at the south and north ends of the net respectively; and from an astronomic station at Pouce Coupé in the Peace River area through the medium of the survey of the interprovincial boundary southward along the 120th meridian. All three of these determinations are subject to errors of unknown magnitude due to the deflection of the plumb line. The third is also affected by any errors, incidental to the survey of the 120th Meridian boundary. The degree of agreement between these determinations and the true geodetic position of this net is awaited with interest.

The methods used in this work were designed with an eye to future improvement and inclusion of this net in the adjusted triangulation net of Canada. See map of the net on page 15.

British Columbia.—The season of 1924 saw the completion of the arc of primary triangulation along the British Columbia coast which had been initiated in 1909. The mountainous character of the country, the prevalence of fog, long lines and the varying size of parties all combined to make this arc a most difficult one to complete. The total length of the arc with one long extension to the southern end of the Queen Charlotte islands is about 700 miles.

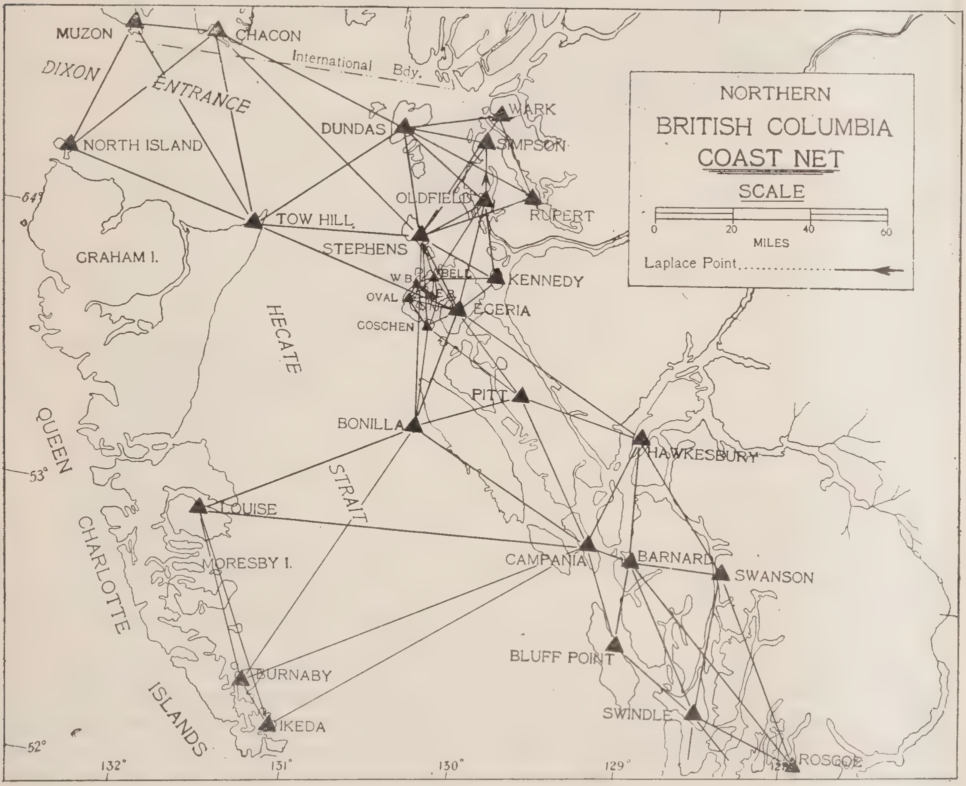
A station was established near the railway line at Prince Rupert from which a precise traverse eastward along the Canadian National railway will be extended during 1925.

Near Victoria, B.C., the Canadian triangulation was connected to a branch of the triangulation system of the United States Coast and Geodetic Survey, which had been specially completed for the purpose. Near Prince Rupert this triangulation provides the geographical datum for the Southeastern Alaska triangulation of the United States Survey, which in turn will supply the same basis for triangulation through Yukon territory, from which the triangulation of Alaska will eventually receive its basic datum of co-ordinates, the North American Datum.

Thus through the co-operation of the two countries a continuous arc of triangulation will be completed from California to the Arctic ocean. This is one of the longest north-south arcs of its kind and is therefore of value in the study of the size and shape of the earth, aside from the important geodetic control it provides. The connections at the north and south ends are shown in the plates on pages 17 and 18.

Northern British Columbia Coast Triangulation

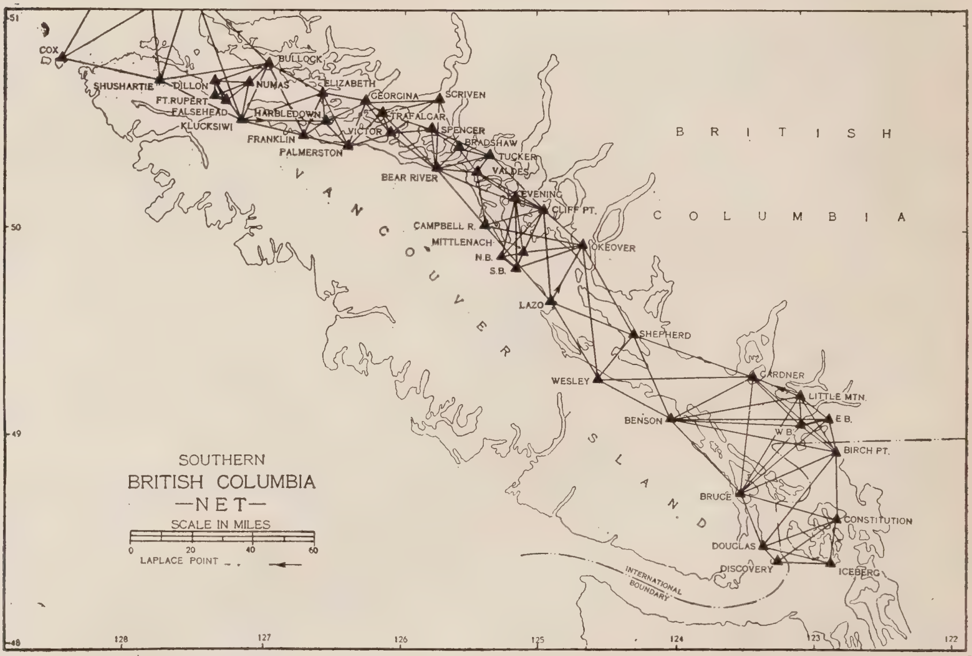
The plans for the season included the final location of a base line not far from Prince Rupert, B.C., on Porcher island, along the northerly side of Kitkatlah inlet; the connection of this base by angular measurements with the main scheme of the triangulation; the extension of the triangulation across Hecate strait to the southerly part of the Queen Charlotte islands and establishment of supplementary stations there; and the fixing of an initial azimuth line from which to extend a proposed precise traverse, eastward from the coast, along the main line of the Canadian National railway. With the completion of this work the main triangulation along the British Columbia coast was finished.



The parties were taken from Prince Rupert to Kitkatlah inlet, on Porcher island, which was the most convenient place for starting the season's operations. The motor launch *Metra* was employed, as usual, for transportation.

It was necessary to include a base line in the survey in this vicinity in order to maintain the required strength of the triangulation, particularly as it is near the junction of the Canadian net with the Southeastern Alaska system. It was an exceedingly difficult piece of country in which to find an approximately level line, four to five miles long, from which a good expansion could be made into the main net, and where the cost of clearing the base line would not be excessive. The preliminary location of the base line was made in 1916 by the present Director, and it is the only possible location with the desired requirements in that district.

The triangulation was successfully carried across Hecate strait to the Queen Charlotte islands, during 1924. This was very gratifying, particularly as the same scheme had been attempted in 1923 with indifferent results, owing to the prevalence of fog and other adverse weather conditions and the fact that the figures involve the longest lines and the largest triangles on the survey to date. The longest line from Campania to Louise, is ninety-eight miles in length and the largest triangle has approximately thirty-one seconds of spherical excess and covers an area of about two thousand three hundred square miles. This triangle was closed with an error of 0·26 of a second of arc. Electric signal lamps with large bulbs, using a current of 12 to 16 watts, were used on these long lines. On the line mentioned above, the light was visible to the naked eye.



The triangulation connection to the Queen Charlotte islands necessitated frequent trips to and fro across Hecate strait which has a reputation for bad weather. Owing to the comparative shallowness of the water and the numerous tidal currents, very little wind is required to stir up a nasty sea for a small boat like the *Metra*. It takes from seven to ten hours to cross the open water, depending on where the crossing is made. The last return trip was made with eighteen men on board, two observing outfits and a quantity of other equipment; there was a decided feeling of relief when the anchor was dropped on the mainland side.

The azimuth line was established along the Canadian National railway, about five miles from Prince Rupert, B.C., with the first station near Kaien siding. It is about three miles in length and is connected with the primary triangulation net. The line runs through heavy timber on Ridley island and after partly clearing this, towers had to built on each end of the line to provide intervisibility.

This concluded the main triangulation work on the northern British Columbia coast. A connection was made in 1923 with the Alaska Boundary survey and a preliminary computation gave the following approximate geographical co-ordinates for station Dundas, one of the stations in the connection:—

—	Southeastern Alaska Datum	North American Datum	Difference
Latitude	54° 31′ 11″·947	54° 31′ 18″·465	6″·52
Longitude	130 55 00″·689	130 54 57″·925	2″·76

It will be seen that the surveys are on different datums and the difference in the results shows the discrepancy between them, which is due to the inclination of the vertical, and is not an indication of the accuracy of the surveys.

The *Metra* gave good service as usual. Besides being used for the transportation of the triangulation parties, she provided for the needs of the base line party thus saving the expense of chartering another boat.

Secondary Triangulation Alberta-British Columbia Boundary

The completion of this work in 1924 brought to a close the program of three seasons work commenced in 1922. The operations of the season of 1924 comprised practically all of the angular measurements, the measurement of a base line at the northern end in Sheep Creek pass and the occupation of two Laplace stations at the two ends respectively.

From its southerly extremity the boundary follows the continental divide northward to the intersection of the same with the 120th meridian. A survey of the latter was being made southward towards the divide. The location of this intersection had for years been considered to be in the vicinity of Jarvis pass, but from the reconnaissance of 1923 it was found to be 10 miles east and 25 miles south of this point, near the high range on the south side of Sheep Creek pass. This permitted the northern end of the projected triangulation to be abandoned, upon which a new base line was located in Sheep Creek pass.

It was a source of satisfaction when Mr.Cautley the Federal and Alberta representative on the Boundary Commission entered the Sheep Creek pass from the north in the projection of the 120th meridian boundary, to find that the meridian, as projected, intersected the base line only a few feet from West Base, and that the official intersection of the meridian with the Continenal Divide came within a short distance of the geodetic station Haig, thus permitting a splendid tie of the meridian with the triangulation at this point.

To ensure the completion of the work in 1924 three angle measurement parties were organized, with a fourth party doing general supervision and rendering assistance where necessary. A further unit occupied the two Laplace stations and measured the base line at the northern end.

The division of the angle measurement among the three parties was as follows:—

One party commenced at the base line at the southern end in the Yellowhead pass and moved northward along the divide by way of the Miette valley and pass, Stony river pass (Shale pass), Colonel pass and creek and thence into the valley of Moose river, finishing the season at Moose pass. See map on page 15.

Another party commenced just north of this point at the mouth of Carcajou creek (Wolverine creek) and worked north by Bess and Jackpine passes to the middle forks of the Jackpine river. This party then returned to Moose and Robson passes and filled in a gap between the work of their own and that of the first named party.

The third party proceeded directly to Sheep Creek pass at the northern extremity of the work and here in this magnificent open valley five miles long by three miles wide in the heart of the Rockies on the very summit of

Tower used on Secondary Triangulation on Vancouver island. The instrument stand is a big, dry cedar, well guyed. Around it the tower has been built to support the engineer. Such a stand is seldom solid enough for geodetic triangulation, but by the exercise of great care it was found suitable in this case.

Alberta-British Columbia Boundary Triangulation—Cairn and signal at *Swank* Geodetic Station.

Alberta-British Columbia Boundary Triangulation—Temporary cairn and instrument station at *Pang* Geodetic Station. The signal has been erected in a temporary cairn, while the main station is occupied by the theodolite, since another engineer is sighting on the signal from a distant mountain. When the work is completed the signal and large cairn will be rebuilt over the station mark.

Alberta-British Columbia Boundary Triangulation—Pack train of one of the Engineer's Parties crossing Dead Man Pass.

the divide, a base line was located, three miles long, without any obstructing timber. A satisfactory expansion from the base line to the main net was obtained. The angular measurements were continued southward as mentioned above, and were made with $6\frac{1}{4}$-inch transits reading to 10 seconds. The repetition method with 6 repetitions on the angle, circle right, and 6 repetitions on the explement, circle left, were employed. Pointings were made on pole signals set in rock cairns built over the station marks. Assistance was also given to the second named party in filling in the gap mentioned above.

The instruments and outfit for the occupation of the Laplace station and the measurement of the base line at Sheep Creek pass were transported by pack train. This party left Jasper the middle of July, completed their work and returned before the middle of August.

The other sections of the work were completed and the last outfits left Jasper by the end of the first week in September. At this time snow on the upper peaks and passes indicated the close of the season.

The country traversed by this triangulation net is one of the most magnificent stretches of the Rocky mountains. Wonderful scenery, with rugged peaks, large ice fields, a profusion of Alpine flora and grasses, sulphur springs and generally brilliant weather during June, July and August, make this area one of surpassing attraction. No minerals were noted, but game is quite plentiful, a few deer, many caribou, with an occasional grizzly bear and mountain goat which become more numerous to the north of Big Shale mountain.

Flying is quite feasible. For hydroplanes the country is not adapted, but safe landings for aeroplanes are possible, with little or no preparation, at a number of places, such as at Sheep Creek pass and the glacial flats between Berg and Adolphus lakes on Robson pass.

Alberta-British Columbia Boundary Triangulation—The rock cairn marks the intersection of the 120th Meridian Boundary with the Sheep Creek base line at the northern end of the Boundary Triangulation. Twelve feet to the right is the signal erected over *West Base* Geodetic Station.

SUMMARY OF RESULTS

Triangulation, 100 miles (length of net from Yellowhead pass to Sheep Creek pass); base lines measured, 2; Laplace stations established, 2; triangulation stations established, 35; Interprovincial Boundary monuments located, Yellowhead pass 2, intersection with Sheep Creek base 1, intersection of 120th meridian with continental divide, 1.

Precise Traverse and Primary Triangulation Along the 49th Parallel

Field operations for the triangulation along the 49th parallel, from the 109th meridian eastward to the Lake of the Woods, will probably be completed in 1925, and, with the necessary computations, will conclude Canada's portion of the twelve hundred and fifty mile arc being carried out in co-operation with the United States Coast and Geodetic Survey.

Precise Traverse.—To meet the requirements of the International Boundary Commission, it was necessary to complete the precise traverse between Emerson, Manitoba, and Lake of the Woods during the season. The outfit was moved from the Estevan, Saskatchewan, section to Sprague, Manitoba, and the traverse begun on May 25 from the eastern end. The accuracy of the work cannot be checked until a loop is completed either by traverse or triangulation and extra precautions were necessary to keep within the required standard. For example, the check chainage with steel tapes was carried on with the purpose of checking the accuracy of measurement rather than to merely detect blunders which is the usual function of this operation. This method requires more time; nevertheless the linear measurement of the seventy-eight miles of traverse was completed by July 21, the angle measurement for the traverse by July 29, and the angle measurement at four primary stations, necessary as a connection with the United States Coast and Geodetic Survey triangulation along the 98th meridian, by August 4.

The Canadian National railway between Emerson and Warroad is not very suitable for precise traverse, as the eastern part has many curves and runs mostly through swamp. It was necessary to build one tower on the ice and complete the observations at this station before the ice disappeared; eight miles of line was cleared and eleven miles posted due to curves in the railroad alinement.

The main azimuth lines, seventeen in number, were all of satisfactory length, and three Laplace points were observed to ensure the standard of accuracy in azimuth. Where the secondary lines, along which the chainage was carried, make a loop with the main azimuth lines, the total error of closure for the loop, if thrown on any direction of chainage as a single error, will affect the length of that main azimuth line by less than 1 part in 100,000.

The algebraic sum of the discrepancies between the invar and steel chainages on the different courses—that is the difference between the total length as obtained by invar and steel—amounted to 1 part in 108,500. Probably a better indication of the class of work is given by the fact that the sum of the same discrepancies without regard to sign amounted to only 1 part in 43,900 for the total distance.

Station Preparation.—Two parties carried on all station preparation as well as line cutting and preparation on the precise traverse.

Direction Measurement.—Difficulties due to refraction had been previously encountered in this area, and a large number of observations had already been taken. Before results which could be accepted with confidence were obtained, a total of 238 sets of observations had been observed, or an average of fifty-nine and a half sets at each station (the usual programme is sixteen sets). Refraction appears to cause considerable difficulty over the prairie, due probably to the fact that many lines must necessarily pass close to the surface of the earth.

Angle measurement was carried forward and completed to the stations Mohall-Gainsborough about the 101st meridian, and it is hoped the remaining section of 39 stations will be completed during the season of 1925.

SUMMARY OF RESULTS

Station Preparation.—Towers built on 190 miles of triangulation, including 49 forty-five-foot towers built, and 2 seventy-foot towers repaired; 78 miles of line prepared for precise traverse, including 8½ miles of scrub and brush cut, 7 dirt stands and 19 standard piers built.

Direction Measurement.—Seventy-eight miles of precise traverse completed, including 11 miles posted, 78 miles chained with invar and steel, 11 miles of levels, 31 primary stations completed, 42 secondary stations completed giving a total of 161 directions measured; 100 miles of triangulation completed, including 25 primary stations completed, 6 reoccupied, 1 supplementary station completed, 19 secondary points located by three directions, 15 by two directions and single directions on 17 secondary points, giving a total of 253 directions measured.

Primary Triangulation Upper Ottawa River District

The reconnaissance was started for the season at one of the lines of the previous triangulation 25 miles above Pembroke and was continued to Mattawa. On the Quebec side of the Ottawa river hills from 800 to 1,000 feet in height provided a splendid outlook over the lower southern, or Ontario, side of the river so that most of the lines crossing the river were easily selected. The lines parallel to the river, however, were more than usually difficult on both sides on account of the flatness and heavily wooded nature of the hilltops.

The stations on the Quebec side were close to the river, were fairly easy of access, and were consequently cheaper and easier to prepare than those on the Ontario side which had to be placed some distance from the river to obtain a net of sufficient width.

A base line and base net were selected near Pembroke, Ontario, which necessitated only three extra stations to give a strong connection with the main scheme.

Supplementary stations were introduced into the net as needed, where primary stations were distant from the river, to give convenient control for mapping. Two of these were used at once by the engineers of the Hydro Electric Power Commission of Ontario in a survey of a section of the Ottawa river. Five azimuth stations were located and occupied for the engineers of this commission.

Time switches were used again to operate the signal lamps, making it possible to reduce the angular measurement party to one assistant, two lightkeepers and a cook, thereby effecting a considerable reduction in expenditure over the older method of placing a lightkeeper with each lamp. The lightkeepers found it very difficult to give the lamps the proper elevation when the observing station was on lower ground than the light, especially on lines crossing the Ottawa river from the fairly high hills of the Quebec side to the low ridges on the Ontario side, and it was necessary at times to use helio in order to identify the position of the observing station for the lightkeepers. Although considerable time was lost due to this fact, the economy effected by the time switches outweighed this disadvantage.

SUMMARY OF RESULTS

Reconnaissance, station preparation, and angular measurement work advanced about 75 miles. New stations selected, 13 primary and 3 supplementary; stations prepared 15, at 14 of which concrete monuments were set, and at 7 of which towers were built; angular measurements completed at 16 primary and at 3 supplementary stations; numerous lighthouses and church spires connected with the scheme.

Secondary Triangulation Along the Quebec and Lake St. John Branch of the Canadian National Railways

The party was assembled on May 13. Heavy timber on all of the hills necessitated the building of towers at all main stations, and even under these circumstances considerable timber cutting was required. An unusually wet

season delayed the progress of the work. The angular measurements were made as before by the repetition method, using a $6\frac{1}{4}$-inch transit, reading to 10 seconds.

SUMMARY OF RESULTS

Reconnaissance, station preparation, and angular measurements advanced about 60 miles. New station selected, 16 main and 1 supplementary; stations prepared 16, at 15 of which towers averaging 29 feet in height were built; angular measurements completed at 26 main stations and 3 supplementary stations; astronomical stations were cut in at Lake Edward and Rivière-à-Pierre.

Gulf of St. Lawrence Reconnaissance for Primary Triangulation

The coast line of Anticosti island from South West Point lighthouse to Heath point, generally speaking, is low. The general slope of Anticosti island is from the south upward towards the north. The north coast from Heath point west to Charleton Point lighthouse is different from the south coast, in that at the east end there is a series of bays and capes where landings can only be made at the endings of the bays as the capes are steep cliffs with bases awash and heights exceeding two or three hundred feet. The water for some distance from the shore is quite shoal and navigation is difficult.

The country on the north shore of the gulf of St. Lawrence from Wolf bay east is a series of scattered, bare, rocky ridges, approaching five hundred feet above sea level. Hill tops below four hundred feet elevation are rounded off. Travelling through this country on foot was difficult on account of the presence of many lakes and ravines. These ravines have steep walls and in most cases are filled with a tangled mass of stunted spruce and brush and the absence of good portages on the rivers makes progress slow and laborious, as it is always necessary to force a passage through dense brush when attempting to travel close to water level in this locality.

SUMMARY OF RESULTS

Reconnaissance work was carried out over 200 miles of the coast of Anticosti island with a view to running a precise traverse from Southwest Point lighthouse to cape Observation. Eleven triangulation stations chosen and established between Wolf bay and cape Mecatina. Reconnaissance completed from Watshishu to vicinity of Mutton bay—175 miles—between longitude 62° 45′ and longitude 59° 00′.

Primary Triangulation, Cape Breton Island, N.S., and Chaleur Bay District, N.B.

Parties were organized at Sydney, N.S., on May 19 to carry on the work required to complete the triangulation across Cabot strait begun in 1923 to connect Newfoundland with the northern section of Cape Breton island. One observing party proceeded immediately to cape Smoky, but the party destined for St. Paul island was prevented from sailing for about week by the presence of heavy drift ice at the entrance of the gulf of St. Lawrence.

One of the difficulties in observing experienced in 1923 was on the line from St. Paul island to cape Ray, Newfoundland. In a stay of two months at the St. Paul end of the line, the conditions of low elevation, fog, and wind were such as to completely obscure this line, but in 1924 weather conditions were so favourable that within nine days this work had been completed, upon which the party proceeded to cape Ray, Newfoundland.

Thus, early in June, the termini of the longest line in this scheme, cape Smoky, on Cape Breton island, to cape Ray, Newfoundland, 92 miles, were simultaneously occupied and the watch for lights commenced. Added to the prevalence of fog was the possibility that owing to insufficient elevation—slightly over 1,200 feet at each station—a normal value of the co-efficient of refraction would scarcely clear the line of sight and the resultant observations might be very inaccurate due to poor images. Observations were secured on the night of June 26 and verified a few nights later. The separate results agreed within a very narrow range. No difficulty was experienced in seeing the electric signal lights with the naked eye, so perfect were the atmospheric conditions, and this condition of visibility greatly facilitated the speed, and eased the strain on the observers.

The observing party was at once moved to the Chaleur bay area in New Brunswick, while the remainder of the Newfoundland work was completed by the end of July, after which this party also moved to the Chaleur Bay district.

The St. Lawrence River triangulation had previously been completed east and south along the Gaspé coast to Percé, while the reconnaissance along Chaleur bay had been finished and towers erected. Owing to the limited number of men available while the far east work was being completed, it was felt advisable to commence observing at the Campbellton end in the base net, where a small party could work economically on short lines. Observations were prosecuted during the remainder of the season with vigour, with the result that but four more primary stations remain to be occupied to complete the connection at Percé with the St. Lawrence triangulation.

The Chaleur Bay triangulation is productive of a large number of supplementary points. The position of ten lighthouses and four church spires have been fully verified, and it is to be noted that these positions are frequently of even greater immediate service than the triangulation points on account of the grater convenience of their location. As in former years particular attention has been paid to the monumenting of the stations. Wherever possible a subsurface concrete slab with disc bolt has been placed under the standard monument. In only a few cases has this method proved impracticable.

A tower building party operated in the district lying on both sides of the Canadian National railway in northeastern New Brunswick, completing the erection of six seventy-foot towers, one sixty-foot tower, and two forty-five-foot towers. This party disbanded in November, 1924, but was required to be made up again in January, 1925, to build a seventy-foot tower southeast of Chatham, New Brunswick, at a site which was inaccessible, owing to swamps, until the ground was frozen.

SUMMARY OF RESULTS

Direction Measurement: Four stations occupied in the connection of Cape Breton island with Newfoundland. Eleven primary stations and one supplementary station occupied in the Chaleur Bay area, where accurate positions for 10 lighthouses and 4 church spires were also obtained.

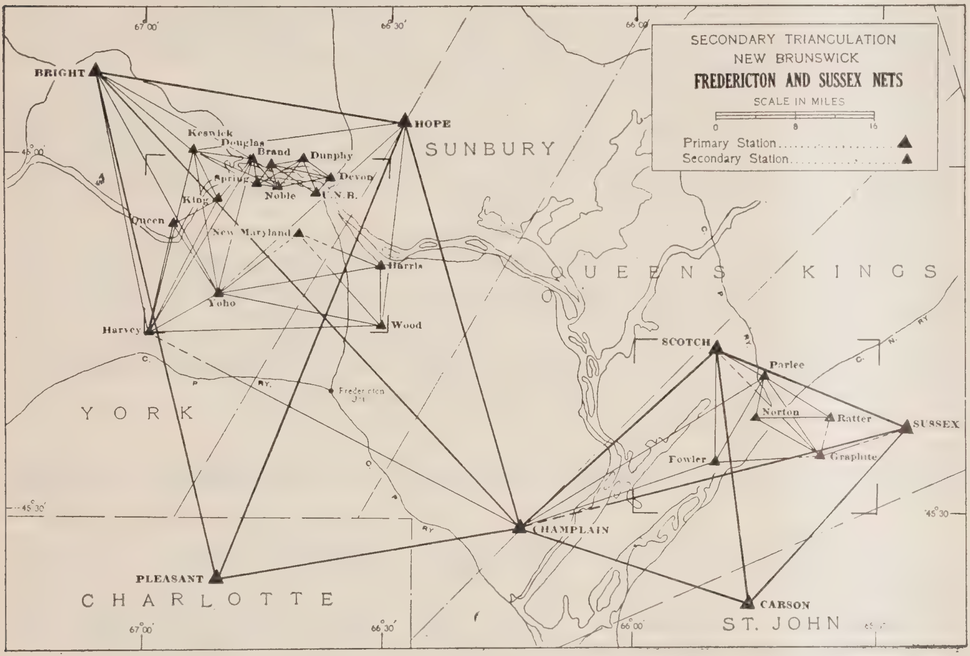
Tower Building: 7 seventy-foot, 1 sixty-foot, and 2 forty-five-foot towers were built.

SECONDARY TRIANGULATION—VICINITY OF FREDERICTON, NEW BRUNSWICK

This party had instructions to complete a secondary triangulation control for topographic mapping of the above district, which comprised over 400 square miles between latitudes 45° 45′ and 46° 00′ and longitudes 66° 30′ and 67° 00′. Six stations of the secondary net in the Sussex, New Brunswick, area and three in the city of St. John, New Brunswick, were occupied for angular measurements before those in the Fredericton area were commenced.

The primary triangulation line Bright–Hope, established in 1915, was used as a base for establishing the secondary triangulation.

The latter half of May was spent in reconnaissance and early in June a tower building party of five men was organized. Towers were finished, monuments placed, signals erected for day observations and the party disbanded on August 19. Excellent weather favoured the work of this party.



During the month of June the usual foggy weather prevailed along the coast, greatly retarding the progress of the angular measurements in the vicinity of St. John, New Brunswick.

Work in the Fredericton area was completed by September 20 and the party disbanded.

The engineers in charge then proceeded on primary reconnaissance, and spent three weeks completing the selection of stations along Northumberland strait.

They then proceeded to Digby, Nova Scotia, and spent three weeks on reconnaissance southward from Digby in the direction of Yarmouth, Nova Scotia.

SUMMARY OF RESULTS

Reconnaissance: Fifteen new stations located.

Station Preparation: Five towers built, averaging 36 feet in height; one tower (at primary station Hope) raised 7 feet and reinforced; standard monuments constructed; signals erected at 18 stations for day observations.

Angular Measurements: Nine stations occupied; observations made from 17 stations on most of the church spires and prominent buildings of the area.

PRECISE LEVELLING

Three precise levelling parties were in the field in the summer of 1924—the first being engaged in eastern Ontario and the Eastern Townships of Quebec, the second in northern Quebec to complete a line through northern Ontario and northern Quebec, terminating at Three Rivers, P.Q., and the third in southern British Columbia between Hope and Penticton.

Apart from the general utility of the line of levels in northern Ontario and northern Quebec, in fixing exact elevations at the crossings of the many important rivers intersected in its course it will be most helpful in strengthening the general precise level net of Canada since it forms a direct tie line between the eastern and western portions of this net.

All precise level bench-marks established by the Geodetic Survey in the Maritime Provinces were inspected during the fiscal year in order to note their state of preservation and to make the necessary revision in their descriptions. Most of them were established from ten to fifteen years ago.

The new levelling rods of the type introduced in 1923 and known as invar rods, were used again in 1924. They continued to give satisfaction both in the field and when subjected to standardization tests at Ottawa.

Precise Levelling in Eastern Ontario and Eastern Townships of Quebec

The season's program for this party was a continuation of the work in hand at the close of the 1923 season. In the portions of Quebec and Ontario adjacent to the United States border four precise level lines—amongst the first to be run by this Survey—were relevelled during 1924, partly in order to improve the accuracy of the levelling and partly to provide a more abundant supply of permanent bench-marks to give the requisite detail control in these districts.

The engineer in charge established camp at Lacolle, Quebec, and started levelling at the United States Coast and Geodetic Survey bench-mark at Rouse's Point, New York. The Canadian National railway was followed to St. Johns, thus connecting up the 1923 relevelling between Sherbrooke and St. Johns with the Rouse's Point bench-mark. Returning to Cantic, a junction point on the Rouse's Point–St. Johns line, about 5 miles north of the International Boundary, the levels were extended along the Canadian National railway through Valleyfield and Coteau to St. Polycarpe Junction, thence westerly along the Canadian Pacific railway to Bedell and southerly along the Ottawa-Prescott branch to Prescott. From this district the party moved to Lennoxville, Quebec, and spent the remainder of the season, till October 10, in running two lines to the International Boundary, one following the Canadian National railway to Norton Mills and the other following the Canadian Pacific railway through Megantic.

On the above four lines, the first three of which were originally levelled in 1907-08 and the last in 1911, 87 bench-marks were established in the first instance; the retracement in 1924 disclosed that 25 of these, or 29 per cent, had been destroyed or in a few cases had become so obviously unsuitable as to be useless. Ninety-eight new bench-marks were established, practically all of which may be depended upon to possess permanence and stability of a high order. The new bench-marks may be classified as follows: Concrete bench-mark piers, 25; solid rock surfaces, 9; boulders, 2; bridges and culverts, 28; buildings, 34; total, 98.

Precise Levelling in Northern Quebec

The engineer in charge left Ottawa on May 5 for Oskelaneo River, a station on the Canadian National railway almost exactly midway between Quebec and Cochrane. At this point levelling from the west had been discontinued in September, 1923; the program was to complete this line to form a junction with the precise level line along the north shore of the St. Lawrence river. Three Rivers was the point chosen as the terminus of the line, the Canadian National railway being followed to Hervey and Grand'Mere and thence the Canadian Pacific through Shawinigan Falls and down the St. Maurice River valley to Three Rivers. A 21-mile branch, from Hervey to Rivière-à-Pierre, was also included in the season's programme in order to make a tie between the main line of levels and the Quebec-Chicoutimi line (at the present time only completed as far north as Linton).

The close of the levelling at Three Rivers in October marked the completion of what is probably the longest continuous line of levels ever run by one man. Starting in the spring of 1920 at the intersection of the Canadian Pacific and Canadian National railways' main lines near Rennie, Manitoba, some 70 miles east of Winnipeg, the latter railway's transcontinental line was followed right through to Hervey, Quebec, passing en route through Sioux Lookout and Cochrane, Ontario, and thereby spanning the whole breadth of northern Ontario's great rock and clay belts as well as the easterly portion of Manitoba and the northwestern section of the province of Quebec. The total length of this line is 1,252 miles. Local levelling control has been provided by 577 bench-marks established at an average interval of slightly less than $2\frac{1}{4}$ miles. At all river crossings one bench-mark was set, and in many cases two. The line as a whole is in an exceptionally strong position as regards permanency of the field records.

Precise Levelling in Southern British Columbia

The program for this party was the extension easterly of the levels along the Kettle Valley railway which had been discontinued in the fall of 1922 a few miles east of Hope. Progress throughout the season was considerably delayed by the heavy and almost continuous grades for which the route is noted. From the town of Hope to Coquihalla summit, a distance of about 37 miles, the levels had to be carried over a grade of some 3,500 feet; this is typical of the grades encountered in this vicinity.

By the establishment of bench-marks at Penticton, at the southern end of Okanagan lake, during the season both the upper and lower ends of this body of water are now placed on the precise level datum.

Inspection of Bench-Marks

In the past it has been the policy of this Survey, as far as possible, to have all bench-marks inspected as soon as convenient after their establishment and before the results of the levelling are issued to the public. Since a large proportion of the levelling was done ten, twelve or more years ago, it follows that many of the bench-marks have not been inspected for a considerable period.

The necessity for the periodic inspections of bench-marks was emphasized in last year's report. Following the line of action then indicated, two inspection trips to the Maritime Provinces were made in the summer of 1924 and the bench-marks on all our precise level lines east of Rivière du Loup, Quebec, and Edmundston, N.B., were examined, the only exceptions being three lines in New Brunswick which had been inspected in 1923. The line Edmundston-Monk-Quebec Bridge was also included in the 1924 itinerary. In all 717 bench-marks, representing 2,170 miles of precise level line, were inspected; 70 bench-marks, or slightly less than 10 per cent, were found to have been destroyed. (These

figures include the three New Brunswick lines covered in 1923 as noted above.) In order to get an idea of how the copper bolts of which the bench-marks consist were faring a record was kept of the condition of the bolts on most of the lines inspected. Seventy per cent had evidently not been tampered with, being in as good condition as when first installed; 22 per cent were in fair condition, i.e., somewhat defaced by hammering or gouging, but the figures and letters stamped on the copper still legible or partially so; 8 per cent were completely defaced, all marking having been obliterated or in a few cases the bolt removed from the hole. Bench-marks in this condition are not counted as destroyed, however, since even though the chisel line fixing the precise plane of reference has disappeared, the elevation is readily recoverable within a hundredth of a foot or less by reckoning from the centre line of the bolt or bolt hole. The lines inspected were for the most part run in the years 1909 to 1915, a few extra ones being added in 1922-23. A railway motor car was used for purposes of transportation, some 2,800 miles of track being covered in the course of the inspection.

In the months of August and September an inspection was made of the bench-marks established two years previously along the Winnipeg and English rivers, in eastern Manitoba and northwestern Ontario. These bench-marks are practically all in natural rock surfaces adjacent to the banks of the above-named rivers and at the time of installation were referenced by means of blazed trees; during the inspection a stone cairn was constructed at each bench-mark, thus rendering the location permanently recoverable.

Summary of Field Work

The mileage run by each party is shown in the following table, also the percentage of relevelling, the number of standard bench-mark piers built and the total number of bench-marks established, including piers:—

Party	Mileage levelled	Percentage relevelled	B. M. piers built	Total B. M's. established
Eastern Ontario and Eastern Townships.............	291	17	25	98
Northern Quebec....................................	281	12	21	146
Southern British Columbia..........................	188	33	25	72
	760	....	71	316

As mentioned on a previous page, all the work of the first named party was a retracement of old lines, hence the amount of new levelling added to the precise level net during the fiscal year was 469 miles.

Previous to 1924, 17,021 miles of levelling had been accomplished; the total to date is therefore 17,490 miles. Three hundred and sixteen bench-marks have been established this year, which brings the total number at the present time to 5,870, not including those of other organizations with which the levelling of the Geodetic Survey has been connected.

The following table shows in detail the lines run in the fiscal year:—

Line	On Railway	Off Railway	Total
New Levelling	Miles	Miles	Miles
Oskelaneo River to Three Rivers, P.Q.	277·0	4·0	281·0
Hope to Chute Lake, B.C.	187·2	0·5	187·7
Total new levelling	464·2	4·5	468·7
Rerunning Old Levelling			
Rouse's Point, N.Y. to St. Johns, P.Q.	23·0	3·9	26·9
Cantic, P.Q. to Prescott, Ont.	142·2	11·2	153·4
Lennoxville, P.Q. to Norton Mills, Vermont	28·0	1·7	29·7
Lennoxville to Megantic, P.Q. (International boundary)	80·6	0·9	81·5
Total rerunning	273·8	17·7	291·5
Total levelling in the year	738·0	22·2	760·2

The mileage of the levelling since the beginning of the work is distributed among the provinces as follows:—

Province	Previous to 1924	1924	Total
Ontario	5,467	0	5,467
British Columbia	2,264	188	2,452
Quebec	2,078	281	2,359
Saskatchewan	2,088	0	2,088
Alberta	1,519	0	1,519
Manitoba	1,227	0	1,227
New Brunswick	1,096	0	1,096
Nova Scotia	729	0	729
Yukon Territory	458	0	458
Minnesota, U.S.A.	89	0	89
Vermont, U.S.A.	6	0	6
Total	17,021	469	17,490

The mileage is distributed among the railways as follows:—

Railway	Previous to 1924	1924	Total
Canadian National	8,167	250	8,417
Canadian Pacific	5,818	26	5,844
Timiskaming and Northern Ontario	320	0	320
Kettle Valley	72	188	260
Great Northern	230	0	230
Algoma Central	219	0	219
Dominion Atlantic	146	0	146
Quebec Central	109	0	109
White Pass and Yukon	91	0	91
Temiscouata	82	0	82
Ottawa and New York	55	0	55
Pere Marquette	55	0	55
Boston and Maine	40	0	40
Maine Central	36	0	36
Napierville Junction	28	0	28
British Columbia Electric	28	0	28
Quebec Ry., Light and Power Company	25	0	25
Maritime Coal, Ry. and Power Company	12	0	12
Pacific Great Eastern	9	0	9
Michigan Central	3	0	3
London and Port Stanley	2	0	2
Highways and cross-country levels	1,474	5	1,479
Total	17,021	469	17,490

GEODETIC ASTRONOMY, STANDARDS AND BASE LINES

Geodetic Astronomy.—During the year 1924-25 seven of the triangulation stations of the Geodetic Survey of Canada were occupied as Laplace stations, viz., Climax, Sask.; Lucerne, B.C.; Sheep Creek, Alta.; Read, Vita, and McQuade, Man.; and Pembroke, Ont.

Climax is one of the triangulation points near the 109th meridian on the 49th parallel triangulation net. During the summer of 1925 it is the intention to establish four other Laplace stations between Climax, Sask., and Emerson, Man. These five stations will control the direction of the triangulation along the 49th parallel. From Climax the azimuth of the line to Rapdan was measured.

The stations at Lucerne and Sheep Creek are on the Alberta-British Columbia Boundary triangulation, Lucerne at the south end and Sheep Creek at the north. For the determination of the longitude at Sheep Creek special wireless time signals were broadcasted from the Annapolis wireless station at 3 a.m. Eastern Standard time. These signals were well received at the Sheep Creek longitude point and a comparison was made every night between them and the sidereal chronometer. The special signals at 3 a.m. enabled a full set of star observations to be obtained before and after the comparisons. The signals were also received at the Dominion Observatory, Ottawa, the base station for Canadian longitude. The results obtained were most satisfactory, a range of only $0''.05$, among the differences of longitude on five nights. These results are on a par with longitude results obtained by the telegraphic method. The observing party at Sheep Creek experienced splendid weather, and the whole work at the astronomical station and on the base line was completed in nine days.

At Lucerne the longitude station was West Base and the azimuth of the line West Base to East Base was observed, while at Sheep Creek the longitude station was East Base and the azimuth of a line due south of East Base was determined with the astronomical transit, and the angle between that line and the line to the West Base was measured thus determining the azimuth of the line East Base to West Base.

Read, Vita, and McQuade are stations on the precise traverse between Emerson, Manitoba, and Warroad, Minnesota. Three nights' longitudes were observed at each of these stations and two nights' azimuths. At Read, the azimuth to Ingram; at Vita, the azimuth to Sprague, and at McQuade, the azimuth to Guilbault were observed. These three stations were occupied in eighteen days, only two nights were lost on account of bad weather and on every other night the observing conditions were perfect.

The Pembroke Laplace station on the upper Ottawa triangulation is just east of the town of Pembroke. Here three nights' longitudes and two nights' azimuths were observed. The azimuth of the line Pembroke to Stafford was determined, and here again ideal weather conditions obtained.

Before and after the field season observations were made for personal equation, between the field observer and the Riefler clock at the Dominion Observatory.

Base Lines.—One secondary and two primary base lines were measured during the summer of 1924. These were Porcher Island base in the British Columbia triangulation near Prince Rupert, Fairhall-Margaret base in the 49th Parallel triangulation near Killarney, Manitoba, and the Sheep Creek base in the Alberta-British Columbia Boundary triangulation. The time consumed in posting and measuring the latter line was that of a party of six men for four days. The levels over the tops of the posts were measured by two men

and a recorder in part of a day. The elevation of East Base above sea level is 5,280 feet and the difference of elevation between East Base and West Base is 120 feet.

The astronomical and base line operations at Sheep Creek were completed in only nine days while the time spent on the trail from Jasper to Sheep Creek pass and return was twenty-one days. This was exceptional because of the mileage covered, the elevations encountered and the condition of the trails.

Standards.—The work in the Standards Building consisted of standardizing the base line tapes before and after measuring each line. The changes in the lengths of the tapes from time to time are small, but yet of sufficient size to warrant frequent standardization.

In the spring three new fifty-metre tapes and six one hundred-foot invar tapes were obtained. The lengths of these tapes were all determined under the same conditions as the base line tapes. The three new fifty-metre tapes were used on the Sheep Creek base.

Advantage was taken of the visit to England of a member of the staff of the Physical Testing Laboratory, to have a comparison made of one of the metre bars of the Geodetic Survey of Canada with the standard metre bar at the National Physical Laboratory at Teddington. The change in the length of the metre bar between its first standardization in 1914 and now, is less than a micron, which is very satisfactory.

Measurement of Two Primary Base Lines

Porcher Island, B.C.—This party was taken on May 26, by the Geodetic Survey launch *Metra* from Vancouver to Porcher island, where camp was established at the foot of Drys bay.

The locating of a suitable base line proved no small task, as the island is heavily timbered on flat areas and gullied where timber is absent. However, after cutting several trial lines, one was finally selected, the west end of which was southwest of Welcome harbour. This line lies close to the shore along Drys bay, 1,500 metres across the tide flats, extends 2,500 metres through

Base Line Measurement—Scaffold 25 feet high and 20 feet long used in crossing a ravine.

timber to a small bay 250 metres wide which had to be crossed at low tide, and thence 300 metres to East Base. This was the only available location for the line and no base line measured by this Survey has presented such a variety and complexity of problems. At West Base a 35-foot tower was built in order to carry the line of sight over the intervening hills.

Clearing the line of timber was commenced on June 9 and finished June 20. In order to cross the ravines and get over the knolls some thirty-five scaffolds ranging in height from four to twenty-five feet, some as long as twenty feet, were built. Centre posts of equal heights were required to support the tape at the centre. The timber for scaffolding and posting was cut as required along the base line.

The measuring was commenced on July 12, the whole work completed on August 4. Ideal weather conditions prevailed. Near the centre of the line it was necessary to cross a ravine nearly 150 metres wide and at its centre nearly 80 feet deep. By building scaffolds near each side, the middle span was crossed with a 100 metre steel chain. This steel chain was standardized by immediate reference to one of the fifty-metre invar tapes.

The method of measuring has been described in previous reports.

Levels over the tops of the posts to determine the grade correction were carefully measured and also referred to mean sea-level. The length of the base corrected for grade and reduced to sea-level is 7421.5183 metres.

At the completion of the work the camp outfit was shipped to Killarney, Manitoba, and the tapes taken to Ottawa to be standardized.

Fairhall-Margaret Base Line.—This base is about twelve miles north of the town of Killarney, Manitoba. Camp was established near the centre of the base line on August 26. A concrete pier and permanent markings were built at East Base and signals erected at each end. In order to clear a large barn a deflection was necessary near the middle of the line. The base was divided into two sections of 8,900 and 9,600 metres at this point, each being posted, measured and levelled separately. The posts were secured at Killarney and after the work on one section was completed the posts were pulled and brought forward to the second section. A good deal of time was lost on the measurement on account of the high winds blowing the tape. However, the whole work of posting, measuring and levelling was completed on October 2 and the levels tied to a Geodetic Survey bench-mark on the Canadian National railway. This base line is the longest yet measured on the Geodetic Survey of Canada. It is the first example where it was possible to take advantage of the selection and measurement of a side of the main scheme of triangulation as a base.

GEODETIC RESEARCH AND ADJUSTMENTS

The division of Geodetic Research and Adjustments has been actively engaged during the year on several important developments. These included research for a method of determining the proper location of Laplace stations on precise traverses, the preparation of research material for publication, the adjustment of a number of triangulation nets, further adjustment of the precise level net and the work of the statistical section from which geodetic information on the above subjects is furnished to those requiring it.

It is desirable that all field work in connection with triangulation or precise traverse nets be completed simultaneously, including such corrective operations as base lines and Laplace (azimuth) stations. The ideal time to locate Laplace stations is obviously after the errors of the completed field work have been analysed, but as this delay is undesirable it is convenient to localize these

points on the basis of an *a priori* criterion. Such a criterion has been developed for the location of Laplace stations on precise traverses based on the assumption of average errors in various phases of the work, and while it cannot be as thorough as the ideal way it will be of great value to the traverse work.

Special attention has been devoted to preparing for publication a work on Higher Geodesy, which presents in a comparatively easy manner the solution of many problems which arise in an extended geodetic survey. A large amount of work has been necessary to prepare this material for publication.

Adjustment of the Precise Level Net of Canada

During the fiscal year the adjustment of the precise level net of Canada has been continued. The datum on which the adjustment is based is mean sea-level at tidal stations on the Atlantic and Pacific coasts. The fifth differential adjustment, which includes all the field work of 1923, has been completed, and a sixth adjustment was also carried out which introduced lines along the boundary between eastern Canada and the United States. This adjustment included a number of United States lines, running as far south of the boundary as five points considered fixed by the United States Coast and Geodetic Survey: Portland, Maine; Troy, Utica, Buffalo and Salamanca, New York. The inclusion of this additional levelling necessitated the addition of seventeen new conditions with five new control points, making in all eight control points in Eastern Canada, the Canadian points already included being tidal stations at Halifax and Yarmouth, Nova Scotia, and Father Point, Quebec, on the Atlantic coast and the gulf of St. Lawrence.

The method used in adding on the United States level lines and circuits to the adjustment of the old net was the differential method, by which the effect of the new levelling was known at once. This effect was considerable, varying of course from point to point, reaching a maximum of approximately 0.6 foot at Hamilton, Ontario, and falling off to zero towards the coasts. The following examples illustrate how the addition of this section of United States levelling and "held points" has affected the values of elevations of Canadian points obtained after five adjustments of Canadian levelling based on three eastern tidal stations mentioned above and Vancouver and Prince Rupert on the west.

Place	Change in Elevation due to inclusion of certain United States lines of levels
Moncton, N.B.	+ ·11 feet
Rouse's Point	+ ·43
Toronto, Ont.	+ ·55
Hamilton, Ont.	+ ·58
Winnipeg, Man.	+ ·22
Calgary, Alta.	+ ·15
Kamloops, B.C.	+ ·07

Some relevelling in eastern Ontario and southwestern Quebec done during the season of 1924 necessitated changes which have been carried through the adjustments.

The new levelling of 1924, comprising the completion of the long line from Rennie, Manitoba, to Three Rivers, Quebec, is now ready for adding to the net. This brings in two new circuits, first, Cochrane—Three Rivers—Ottawa—North Bay—Cochrane and, second, Hervey Junction—Quebec—Three Rivers—Hervey Junction. These will be added to the net in the next adjustment, which will give adjusted elevations to all points on the precise level lines of the Canadian Geodetic and Topographical Surveys.

British Columbia Coast Triangulation Nets

The British Columbia Coast triangulation net which extends from the 49th parallel of latitude to the Alaska boundary is approximately six hundred miles in length.

To facilitate the adjustment, this net was divided into three separate portions, each of which was adjusted as an entity. The southern part consists of sixty-one conditions comprising thirty-eight angle, nineteen side, two length and two Laplace equations. The central portion has fifty-four conditions including one length and one Laplace equation, and the northern section involves seventy-one conditions with one length and one Laplace equation. Each section of the net was adjusted by the differential method, to show the effect of length, and Laplace controls.

The completion of this section of difficult triangulation supplies data of great value to both federal and provincial authorities. The mapping of tortuous channels, the accurate location of the lighthouses, beacons, reefs and islands that lie off the western coast line of Canada is now being based on the control afforded by the geodetic stations of this net.

Another related net of primary accuracy projected across Hecate strait, joining Queen Charlotte islands with the mainland scheme, has corrected the positions of lighthouses on the eastern side of these islands by amounts up to one mile. The triangulation has not been carried to the western side of the islands.

The adjustment of the main coast line net, also enables Canada to co-operate with the United States by providing a connecting link between the triangulation of the Pacific coast south of the 49th parallel and that of Alaska.

Alberta-British Columbia Boundary

The adjustment and evaluation of geographic positions of the secondary triangulation along the Alberta-British Columbia boundary from Yellowhead pass northwest to Sheep Creek pass is now nearing completion.

The triangulation is based on the astronomical determination of the position of West Base (near Lucerne, British Columbia). Field data which were used in the adjustment to increase the accuracy of this work consisted of two measured bases, one at Yellowhead lake and the other in the Sheep Creek pass, and Laplace observations at East Base in the Sheep Creek pass. This isolated datum will stand until such time as this triangulation can be connected with points on the North American Datum.

Precise Traverse, Eastern End of 49th Parallel Net

During the season of 1924 the field work of the precise traverse along the Canadian National railway from Emerson, Manitoba, to Warroad, Minnesota, was completed, and during the following winter the results of the work were prepared for adjustment.

It is intended that this traverse, together with a traverse by the United States Coast and Geodetic Survey eastward from the Lake of the Woods along the International Boundary, and also triangulation by the two national geodetic surveys further east ending at lake Superior, will be adjusted together. Hence, only the preliminary calculations of the 1924 field work have been carried out to date.

Corrections were first made to the measured lengths of the traverse courses, for temperature, grade, error of tape and for reduction to sea-level. In several cases, where the measured traverse lines were short due to curves in the alinement of the railway line and where the angular measurements might be expected to be in error, main azimuth lines were established connecting traverse stations a longer distance apart (up to 10 or 11 miles).

The traverse lines and main lines constituted circuits; the small angular errors so found were distributed among the traverse stations, and the traverse was calculated to determine the lengths of the main lines.

The distance covered by this traverse was about 80 miles. There were eighteen main stations on azimuth courses, five supplementary stations and thirty-two traverse instrument stations. This resulted in fifty-four measured courses being reduced to seventeen main courses.

Ottawa River Net

The net of primary triangulation along the Ottawa river from the main triangulation in the vicinity of Ottawa to the base line and Laplace station near Pembroke was partially adjusted during the winter of 1924-25. As the base line near Pembroke had not been measured it was impossible to complete this adjustment. Preliminary values of the geographical positions in this area have been secured, which will serve temporarily the requirements of those who need them.

Saguenay River Triangulation Nets

The adjustment of the first net of the Saguenay loop commenced at two stations of the St. Lawrence River net. This net was observed with primary accuracy and was adjusted as a whole.

Above Chicoutimi the scheme was stepped down to shorter sides, and the angular measurements were made with secondary triangulation accuracy. The net was continued up the Saguenay river to and around lake St. John, and near Chambord a base line and Laplace station were established. This section, was therefore, adjusted as a whole.

In the above area connections were made with astronomic piers at Chicoutimi, Roberval, Lake Edward and through the St. John area to Rivière-a-Pièrre. In this way comparisons have been made between the astronomic and geodetic positions of the above piers. Connection was also made at the intersection of the 48th parallel of latitude with the railway; this parallel forms the boundary of a number of counties and information regarding its true position was particularly desired by the Quebec government.

At least one other base line and another Laplace station will be required to complete this net.

Adjustment of St. Lawrence Net

During the past winter the lower St. Lawrence triangulation net has been adjusted and the results evaluated for all stations as far east as Anticosti island and Gaspé. The mode of operation has been to adjust for side and triangle closures first, thus obtaining a position of the net without the corrective influence of bases and Laplace azimuths; then determining the absolute discrepancies in distance and azimuth and subsequently correcting the whole for these latter conditions. This net has been productive of a large amount of information as to the positions of lighthouses, churches, etc., along this main artery of commerce, which is of great value to other departments of the federal service and to the province of Quebec.

Within another year it is anticipated that a closure will be effected near Amherst, Nova Scotia, completing a circuit of triangulation of international importance extending from the mouth of the bay of Fundy through the New England states to Montreal, thence down the St. Lawrence river, Chaleur bay, east coast of New Brunswick and the bay of Fundy. The closure of this circuit will be awaited with great interest by all concerned in geodetic work as it will be the first large closure effected in Canadian practice. It likewise will give rise to a series of new problems requiring considerable research before a definite policy of readjustment can be decided upon.

New Brunswick Secondary Triangulation Nets.—Two secondary triangulation nets in the vicinity of Sussex and Fredericton, New Brunswick, have been adjusted as a basis for topographical work in these vicinities.

A number of other minor nets have been calculated as well as numerous isolated geodetic positions, which have occupied the attention of the division of Mathematical Research and Adjustments.

Geodetic Statistics

During the year this section has been active in furnishing geodetic information to the public. Practically every survey branch of the Dominion Government, has been supplied with geodetic data; in addition, the provincial surveys of British Columbia, Ontario, Quebec, and New Brunswick have received a great deal of information for the correction of their charts and maps. Many private engineering organizations have also benefited from the accurate determination of positions and elevations.

A great many final results have been turned in for record. Particular mention should be made of the final results of three large primary nets—one in Ontario, a second along the St. Lawrence river and a third along the British Columbia coast—which have been completed. In addition, the results of the adjustment of a number of small nets and a great many secondary points scattered over the country have been added to the records of this office. In connection with the precise level system, the latest adjusted elevations have been recorded.

Considerable revision of the geodetic data already on hand has been made during the past year. This is always necessary when new or final values are added.

Field results in connection with the work carried on in different parts of the country have been catalogued and the necessary sketches made for permanent records.

LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia.
Publication No. 2—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.
Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.
Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.
Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.
Publication No. 6—(Withdrawn from publication, as levelling contained is republished in Bulletins.)
Publication No. 7—Geodetic Position Evaluation.
Publication No. 8—Field instructions for Precise Levelling.
Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning.
Publication No. 10—Instructions for Building Triangulation Towers.
Publication No. 11—Geodesy (in press).
Publication No. 12—Mathematical Statistics of the Geodetic Survey of London, Ont. (Distributed at London, Ont.)
Publication No. 13—Errors of Astronomical Positions Due to Deflection of the Plumb Line.
Instructions to Lightkeepers; Use of Electric Signal Lamps, being Appendix No. 4 to Publication No. 5.
The Geodetic Survey of Canada; Operations, April 1, 1912, to March 31, 1922—Publications of the International Geodetic and Geophysical Union, 1922.
Reports of the Section of Geodesy; The International Geodetic and Geophysical Union; Second General Conference, Madrid, 1924; Operations, April 1, 1922, to March 31, 1924.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1918.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1919.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1920.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1921.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1922.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1923.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1924.
Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal Year ending March 31, 1925.

PRECISE LEVELLING BULLETINS

Bulletin A—
Vancouver, B.C., and adjacent district—as far east as Mission, Matsqui and Huntingdon.
Bulletin B—
Abbotsford to Resplendent, B.C.; Spence Bridge to Brodie, B.C.; Mission to Hope, B.C.
Bulletin C—
Saskatoon, Sask., to Prince George, B.C.; Prince Rupert to Prince George, B.C.
Bulletin D—
Calgary, Alta., to Kamloops, B.C.; Revelstoke to Arrowhead, B.C.; Sciamous to Okanagan Landing, B.C.
Bulletin E—
Kipp, Alta., to Golden, B.C.; Bull River to Kootenay Landing, B.C.
Bulletin F—
Calgary to Lethbridge, Alta.; Calgary to Tofield, Alta.; Camrose to Wetaskiwin, Alta.
Bulletin G—
Moose Jaw, Sask., to Coutts, Alta.; Swift Current, Sask., to International Boundary.
Bulletin H—
Irricana to Medicine Hat, Alta.; Bassano, Alta., to Swife Current, Sask.; Empress to Compeer, Alta.; Kerrobert to Unity, Sask.
Bulletin I—
Stephen, Minn., to Regina, Sask.; Regina to Prince Albert, Sask.

Bulletin J—
Napinka to Neepawa, Man.; Minnedosa, Man., to Regina, Sask.; Yorkton to Saskatoon, Sask.; Colonsay to Prince Albert, Sask.; Lanigan, Sask., to Brandon, Man.
Bulletin K—
Emerson, Man., to Port Arthur, Ont.; Sprague to Neepawa, Man.; Portage-la-Prairie to Plum Coulee, Man.
Bulletin L—
Winnipeg, Man., to Kenora, Ont.; Winnipeg to Victoria Beach, Man.
Bulletin M—
Rennie, Man.. to Armstrong, Ont.; Superior Junction to Rowan, Ont.
Bulltin N—
Sudbury to Cochrane, Ont.; Armstrong to Cochrane, Ont.
Index Bulletin, Precise Levelling—Precise Level Lines of the Geodetic Survey of Canada in the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba, and in the northern portion of the province of Ontario, north and west of North Bay.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Ottawa.

INDEX

BASE MAP FROM CHIEF GEOGRAPHER'S MAP OF THE DOMINION OF CANADA
PRINTED BY THE TOPOGRAPHICAL SURVEY OF CANADA, OTTAWA